

Report as of FY2010 for 2009VT45B: "Estimating Soil Phosphorus Concentrations along Erodible Stream Corridors in Chittenden County, Vermont "

Publications

- Articles in Refereed Scientific Journals:
 - ◆ Young, Eric, Don Ross, Caroline Alves, and Thomas Villars, 2011, Influence of soil series on phosphorus forms and availability at two riparian sites in the Lake Champlain Basin (Vermont). J. Soil Water Conserv.: In Press.
- Conference Proceedings:
 - ◆ Valentin, Dorielys 2010. Examining Effects of a Capped Landfill on Groundwater and Alluvial Soils near Indian Brook in Essex, VT. (Universidad Metropolitana). Ana G. Méndez University System 2010 Research Symposium, Sep 10-11, 2010, San Juan, Puerto Rico.
 - ◆ Ishee, Eulaila and Don Ross. 2011. Contribution of streambank erosion as a non-point source of phosphorus to Lake Champlain from streams in Chittenden County, VT. American Society of Limnology and Oceanography, Feb 13-18, 2011, San Juan, Puerto Rico.
 - ◆ Valentin, Dorielys. 2010. Examining effects of a capped landfill on ground water and alluvial soils along Indian Brook in Essex, VT. (Universidad Metropolitana). Third Annual Vermont EPSCoR Streams Project Symposium, Apr 26, 2011, Burlington, VT.
- Other Publications:
 - ◆ Valentin, Dorielys M., 2010, Examining Effects of a Capped Landfill on Groundwater and Alluvial Soils Near Indian Brook in Essex, VT, ANA G. MÉNDEZ UNIVERSITY SYSTEM (AGMUS) 2010 Research Symposium, San Juan, Puerto Rico, Page 38.

Report Follows

Progress Report

Estimating Soil Phosphorus Concentrations along Erodible Stream Corridors in Chittenden County, Vermont

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Abstract

Phosphorus (P) loss from stream bank erosion is thought to be a major and underestimated contributor of P loading to Lake Champlain. Soil variability strongly influences the chemical and physical properties of riparian areas. To assess potential P contribution, we sampled riparian soils along four streams in Chittenden County, Vermont. At 76 erosion sites, we collected over 900 soil samples in depth increments for particle size determination and P analysis. Total P (TP) and soil test P (Modified Morgan's) were relatively consistent across the four stream corridors with means of 625 and 2.2 mg kg⁻¹ respectively. The concentration of both P measurements usually decreased with depth. Bulk density increased with depth but was also relatively consistent across the sites. Texture varied among the stream corridors from high sand to high silt content and was, by itself, only weakly correlated with TP. When coupled to historical measurements of streambank erosion, results from this project provide improved estimates of P mobilized by fluvial systems and contribute to a greater understanding of P dynamics in the Lake Champlain Basin. Eroded features along Allen Brook from 1999-2004 contained 3 MT P, approximately 40% of the TP delivered to Lake Champlain from Allen Brook for that period.

Introduction

Phosphorus loading from stream bank erosion is a major concern in Vermont watersheds, and geomorphic assessment indicates that approximately 75% of the assessed stream and river reaches (757 miles) in Vermont are eroding due to floodplain loss (VT DEC, 2007). Studies have indicated that streambank erosion and associated P can be a large nonpoint pollutant source (Kalma and Ulmer, 2003; DeWolfe et al., 2004). Riparian soil variability influences the form and amount of P in soils and legacy sediments. Variation in the chemical and physical properties of riparian soils also influences the potential for stream bank erosion, and thus affects the susceptibility of this P to erosive fluvial forces. In addition, soil drainage variation in riparian zones can strongly influence soil genesis, total soil P levels, organic carbon, redox patterns, and P mobility through different hydrologic pathways over time (Young and Ross, 2001; Young and Briggs, 2008; Young et al., 2011). Finer-textured sediments can have greater total P contents, but also a greater sorption capacity for orthophosphate (McDowell et al., 2002). The particle size distribution (texture) of both stream bank soils and fluvial sediments appear to be an important constraint on total P content. There is a clear need to quantify the P fractions (total

and bioavailable) in these riparian soils and to develop predictive tools to estimate how much P is coming from stream bank erosion.

Our study had two main objectives: i) sample soils to determine P content within and among soil types along impaired and attainment streams in Chittenden Co., Vermont and ii) estimate historic sediment and P loading due to stream bank erosion on selected streams in Chittenden County over the period 1999-2008 in collaboration with stream bank erosion mapping efforts by Morrissey et al. (2009). Our currently funded project (through Feb, 2012) is using statistically selected samples from this set to quantify the slow-cycling P contribution (Pox) from eroding stream bank sediments into Lake Champlain. We will report the results from these analyses next year.

Methods

Field work. Seventy-six sites along 4 streams in Chittenden County were sampled in 2009 and 2010 (Fig. 1). Allen Brook and Indian Brook were both identified as impaired while Alder and LaPlatte were sampled along attainment reaches. Areas of active erosion were identified via remote sensing by co-investigator Morrissey. Twenty-five locations were randomly selected for sampling along Allen and Indian Brooks, while 13 locations were sampled on Alder and LaPlatte. All remotely identified features were first verified by a site visit. We then sampled at the center of the erosion feature, 1.5 m from the bank edge (Fig. 2). At each site, three soil cores were taken 1 m apart, at four depths: 0-15 cm, 15-30 cm, 30-60 cm and 60-90 cm. These depths were selected to provide P concentrations for the upper soil layers that may reflect historical land use and also for lower soil layers that are representative of soil parent material. This approach resulted in 12 samples per feature unless sampling was impeded by coarse fragments or bedrock.

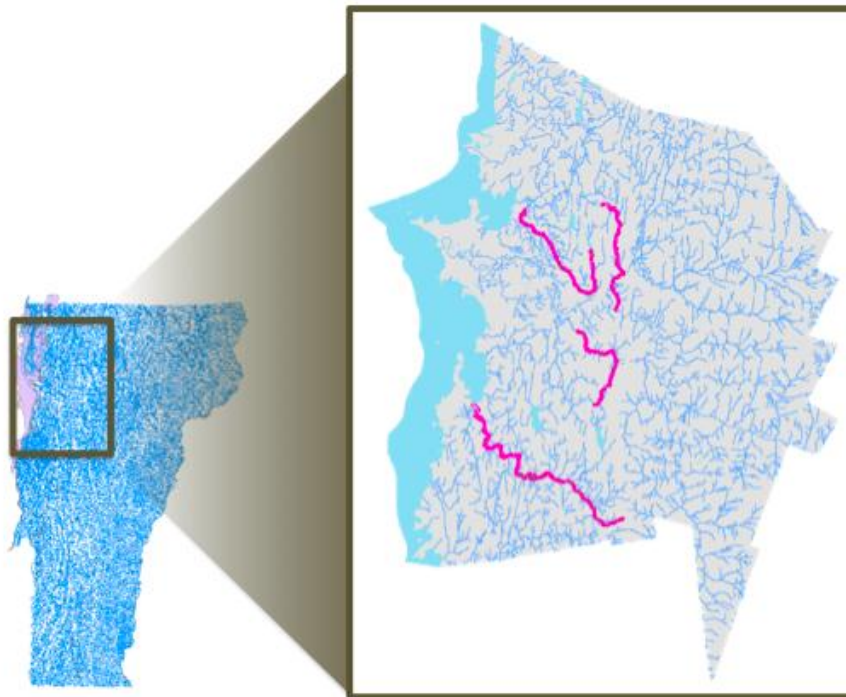


Figure 1. Study location: 4 streams in Chittenden County (clockwise from upper left: Indian Brook, Alder Brook, Allen Brook, LaPlatte River).

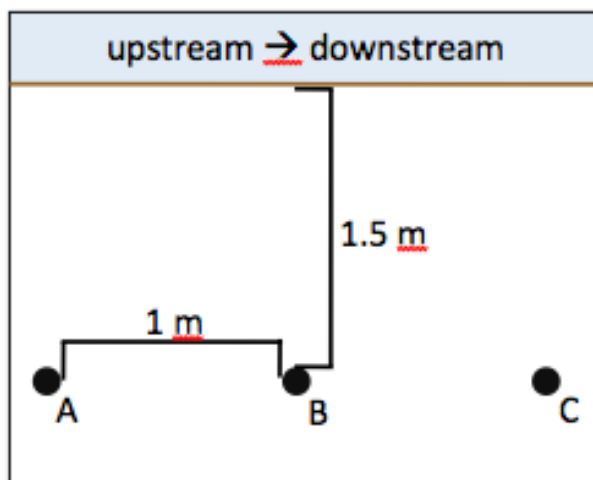


Figure 2. Sampling diagram.

Additional samples were irregularly collected along the slope of the erosion feature when exposure allowed sample collection at depths greater than 1 m. These samples will be used to determine if soil changes take place at these greater depths. Bulk density cores were also taken with a Uhlander device at two depths (approximately 0-15 and 10-30 cm) adjacent to each coring location. All soil sampling locations were georeferenced to ensure a match with the remote sensing data. Approximately 912 soil samples were collected for chemical tests and 456 samples for bulk density and coarse fragment measurements. In addition to this sampling, we dug 18 classification soil pits along the

four streams in collaboration with cooperator Caroline Alves of the USDA NRCS. Samples from these pits have been sent to the National Soil Survey Lab for complete physical and chemical analysis, and the data will be used to definitively classify the sampled soils. In these pits, we also obtained bulk density samples from the lower depth increments that are being analyzed at UVM.

Sample Preparation. Augered samples were air-dried for 3-4 days and sieved through a 2 mm sieve to remove coarse fragments. Most samples were gently ground by hand in a mortar and pestle, however firmer samples with higher clay content were ground using a Humboldt soil grinder (H-4199). Subsamples were taken from each bulk sample after thorough mixing and completely ground and sieved through a 0.25 mm sieve for total P and oxalate-extractable P analysis.

Bulk Density. Bulk density samples were oven dried at 105°C overnight and weighed following removal from oven. Bulk density samples were sieved through a 2 mm sieve to remove coarse fragments (CF). Coarse fragment weight and volume (assumed density of 2.65 Mg/m³) were subtracted from total weight and core volume to calculate weight and volume of soil.

Total Phosphorus. Total phosphorus concentrations were characterized using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) following nitric acid microwave digestion (USEPA Method 3501). The ICP was calibrated with NIST-traceable standards and quality control samples included reference soils and NIST-traceable P solutions purchased from a different vendor than the standards.

Soil Test Phosphorus. The Modified-Morgan soil test P (MM-P) method (Wolf and Beegle, 2009) was used to determine soil test P. Phosphorus concentrations in the extractions were determined colorimetrically on a flow injection autoanalyzer (Lachat QuikChem AE) using the Murphy-Riley procedure.

Particle Size Analysis. Percent sand, silt, and clay was determined using the hydrometer method. A representative 50 g subsample was taken from each sample (100 g for sandy soils) and placed in a 500 mL polyethylene bottle. Soil aggregates by overnight shaking (minimum 16 hours) with

100 mL of 5% calgon solution (sodium hexametaphosphate) and ~200 mL reverse osmosis (RO) water.

Results and Discussion

Soil texture. Particle size distribution in the soils differed somewhat among the four stream corridors (Fig. 3). Allen and Indian had relatively high sand and low clay content whereas Alder and LaPlatte had higher silt and clay. The parent materials for these soils were sediments derived primarily from alluvium, with some input from glaciolacustrine materials. The dominance of sand across all samples sites (Fig. 4) reflects the alluvial source. These soils may have developed on ‘legacy’ sediments from large erosion events related to land clearing in the late 18th and early 19th centuries or from any series of events dating back to the retreat of the last glacier circa 12,000 years ago. Phosphorus content is likely derived from the parent material and our previous work has shown a relationship between texture and total soil P.

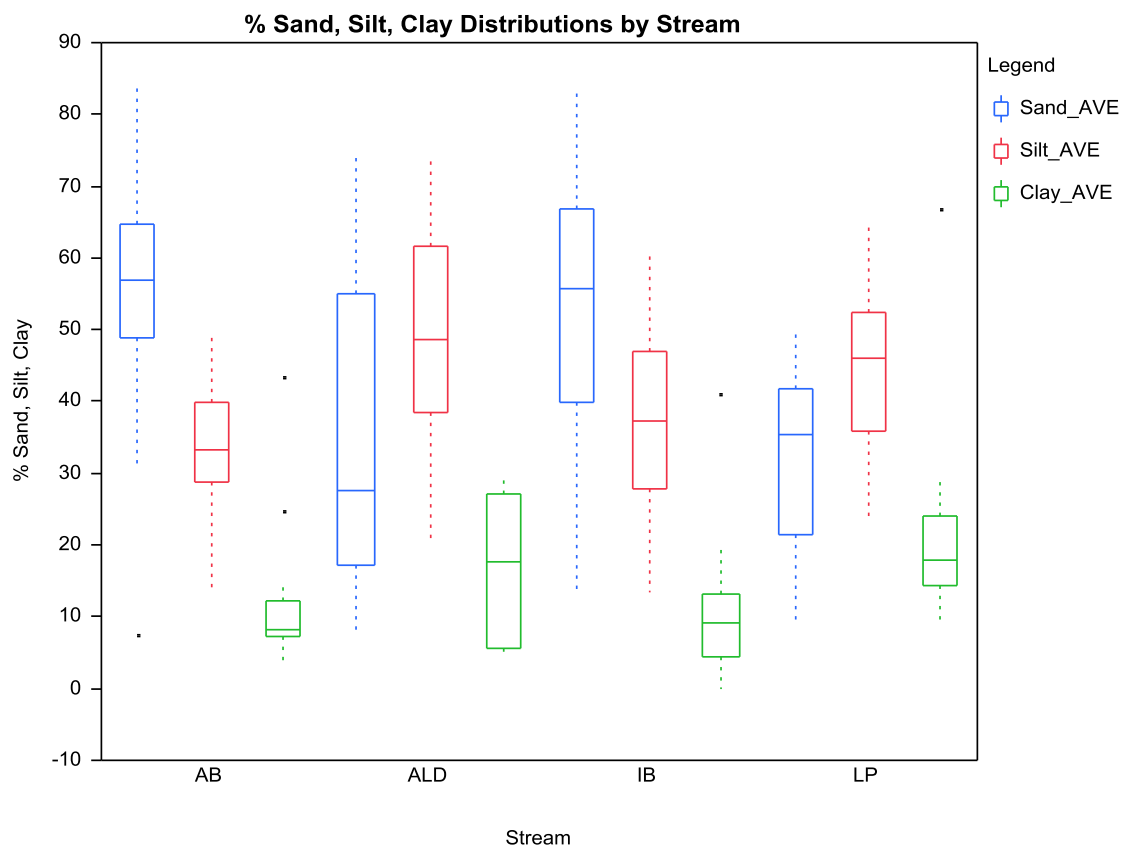


Figure 3. Box plots of the sand, silt and clay distribution along the four stream corridors. AB = Allen Brook, ALD = Alder Brook, IB = Indian Brook, LP = LaPlatte River

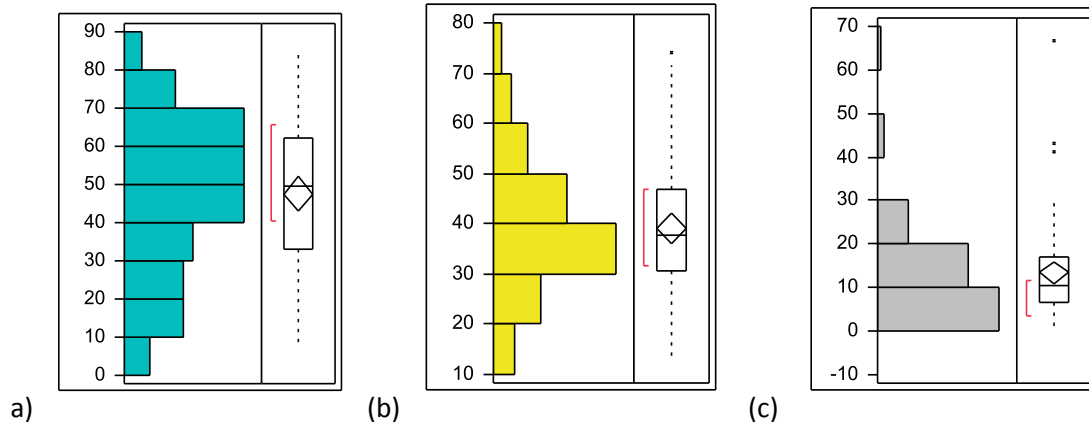


Figure 4. Histogram and boxplots of particle size for all streams: (a) % sand, (b) % silt, and (c) % clay.

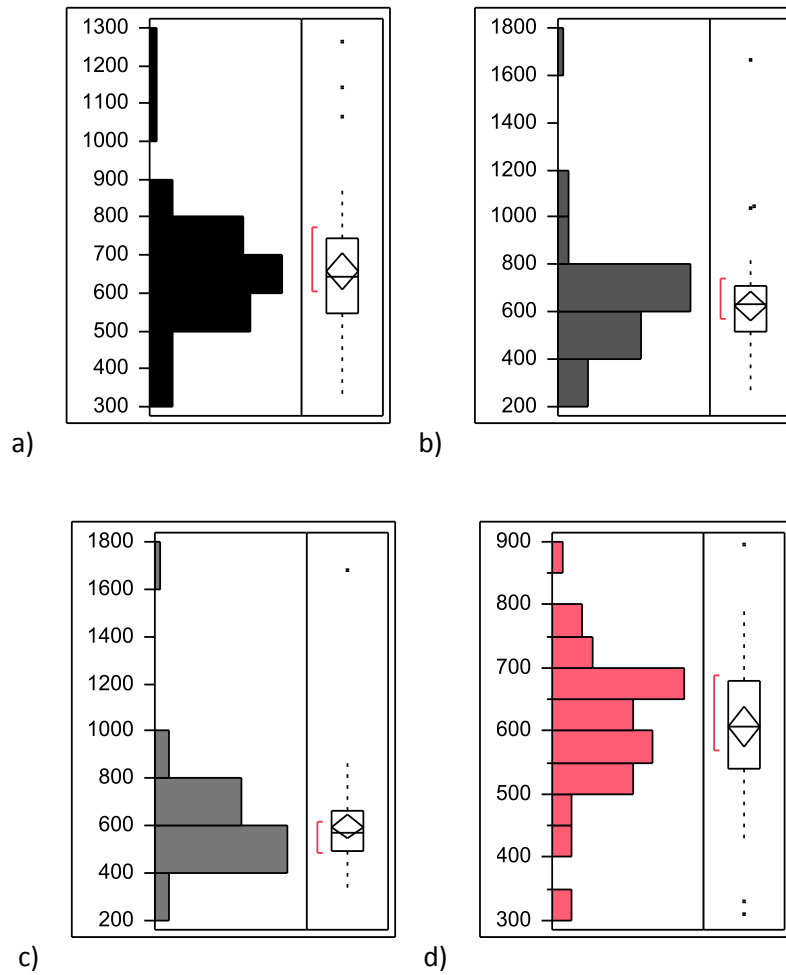


Figure 5. Total P concentration histograms and boxplots for all streams by depth: (a) 0-15 cm, (b) 15-30 cm, (c) 30-90 cm and (d) weighted average representative of all depths. Units are mg kg^{-1} .

Total soil phosphorus. Total P had a wide range across all samples (Fig. 5) but most values fell between 550-750 mg kg⁻¹ soil. This is consistent with previous findings from similar stream corridors in Vermont (Young et al., 2011). Total P is a measure of the maximum amount of P that could be released from sediments after transport. The common procedure used to determine total P, microwave-assisted nitric acid digestion, does not completely dissolve all soil minerals (O'Halloran and Cade-Menun, 2007) yet still represents more P than is likely to ever be released and become bioavailable. Other measurements of P, including soil test P, have been used to predict the readily bioavailable pool and this is always much lower than the total (see below). Our ongoing work is examining the usefulness of a moderately strong extractant, pH 3 ammonium oxalate. This procedure has been found to dissolve the less crystalline iron and aluminum oxides that are known to be associated with sorbed and precipitated P. Redox cycling in the lake can reduce the iron oxides and release associated P. Finding an appropriate test for this potentially bioavailable soil and sediment P remains a challenge. However it is clear that we need to move beyond the use of Total P as a surrogate for potentially bioavailable P.

Soil test phosphorus. The Modified Morgan's (MM) soil test extractant (pH 4.8 ammonium acetate, 1.25 M with respect to the acetate) is used by a number of New England states for soil fertility recommendations. Unlike other common soil test solutions, e.g. Mehlich-III and Bray's, it does not contain fluoride (F), which is an efficient replacer of tightly bound P. This results in MM-P usually being about 10x less than the F-containing extractants. Magdoff et al. (1999) showed that MM-P was a better predictor of immediately bioavailable P than Mehlich-III and can be used to estimate the quantity of sediment P that would easily move into the water column. The concentration of MM-P in the stream corridor soils that we studied was low relative to what is considered optimum for cropped land (7 mg kg⁻¹ is the critical or optimum value). There was little variation among the four stream corridors (Table 1) and concentrations usually decreased with depth. This trend towards lower concentration with depth mirrors that found with Total P and likely reflects both inputs from past land-use and natural soil horizonation in which organic C and associated nutrients accumulate near the surface. Some of the higher concentrations found at lower depth in some samples may have been from buried A horizons, resulting from past erosion and deposition.

Table 1. Mean soil test total P (MM-P) concentrations of sample sites along streams individually and combined.

Stream	Depth Interval cm	<i>n</i>	Mean MM-P mg/kg	SEM*
Allen	0-15	25	3.4a**	0.5
Allen	15-30	25	1.8b	0.2
Allen	30-90***	25	1.7b	0.2
Indian	0-15	25	2.8a	0.3
Indian	15-30	25	1.8b	0.2
Indian	30-90	25	1.8b	0.2
Alder	0-15	13	2.9a	0.3
Alder	15-30	13	2.4a	0.4
Alder	30-90	13	3.1a	0.5
LaPlatte	0-15	13	2.9a	0.5
LaPlatte	15-30	13	1.9a	0.4
LaPlatte	30-90	13	1.7a	0.2
All Sites	0-15	76	3.1a	0.2
All Sites	15-30	76	1.9b	0.1
All Sites	30-90	76	2.0b	0.1

* Standard error of the mean

** Means within a depth with different letters are significantly different at $P \leq 0.05$

*** 30-60 and 60-90 depth categories were combined to represent the lowest depth category

Table 2. Mean bulk density and coarse fragment mass of sample sites along streams individually and combined.

Stream	Depth Interval	<i>n</i>	Mean BD Mg/m³	SEM*	%CF	SEM
Allen	upper**	25	1.0	0.04	5.66	0.02
Allen	lower**	24	1.2	0.04	4.65	0.02
Indian	upper	25	1.0	0.04	1.04	0.00
Indian	lower	25	1.1	0.03	1.16	0.00
Alder	upper	13	0.9	0.11	0.82	0.00
Alder	lower	13	1.2	0.14	0.67	0.00
LaPlatte	upper	13	1.0	0.04	0.40	0.00
LaPlatte	lower	13	1.2	0.04	0.39	0.00
All Sites	upper	76	1.0	0.02	2.44	0.01
All Sites	lower	76	1.2	0.02	2.08	0.01

* Standard error of the mean

** Upper and lower depth classes correspond to 0-15 cm and 10-25 cm respectively.

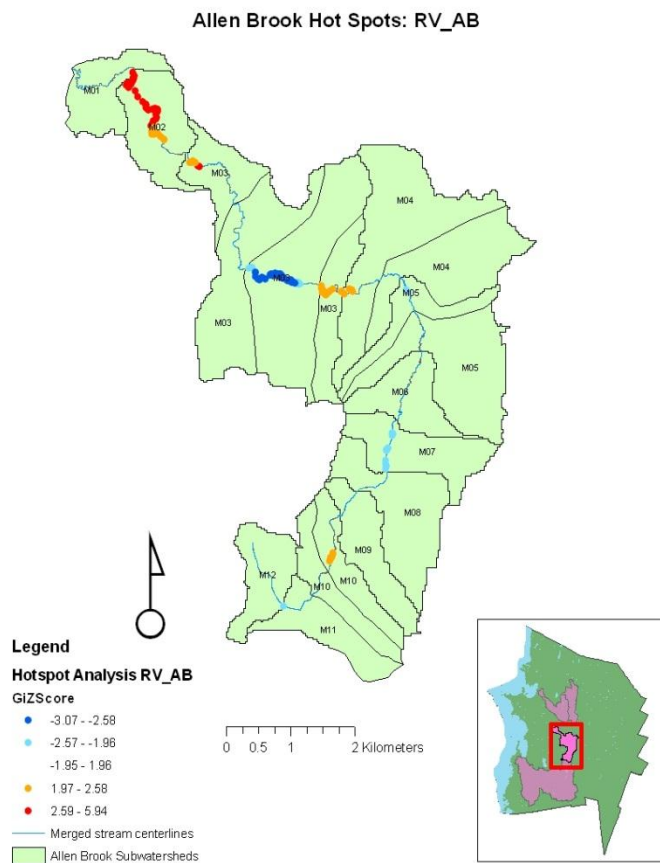
Soil bulk density. Bulk density (BD) was similar among the stream corridors. Higher BD values at the 15-30 cm depth were expected because of less organic carbon lower in the profile (Table 2). Bulk density measurements were taken at multiple depths in pit samples (data not shown) and we used those values for an average BD for depth increments below 30 cm. Coarse fragments (CF) were primarily gravel and stones > 2.0 mm in diameter. These values differed among the stream corridors ranging from a low of 0.4% at Alder to 5.7% at Allen. Because the large fragments are considered inert, a higher %CF translates to a lower total P per volume of sediment. This needs to be factored in when scaling up these results to calculate the P content of eroded stream banks.

Relationships among measured variables. In our previous study of three stream corridors in Addison and Franklin Counties (VT), we found significant relationships between particle size and total P (Young et al., 2011). While the trends are the same in our recently collected data, the relationships we've examined to date are much weaker. The data is currently in the final stages of quality assurance procedures and we will reanalyze when we have a complete and robust dataset. In addition to the data presented above, we will have additional elemental analysis from both the Total P digestion and the soil test extraction. We will examine the interaction between total Ca and P relative to soil texture. Soil test available aluminum (Al) has been correlated with P availability (Bartlett, 1982) and we will include those data to determine possible interactions with particle size. These data, combined with newly analyzed oxalate extractions should provide a variety of approaches to develop predictive tools for stream corridor soil P.

Hotspot analysis. Total P concentrations were interpolated across all erosion features on Allen Brook by applying a regression of percent silt (NRCS representative values) versus TP for Allen Brook samples alone ($y=5.07x + 398.11$; $R^2=0.32^*$). Total mass P contribution was calculated by multiplying TP concentrations and mass of erosion feature yielding a total of 3191 kg TP for erosion between the years 1999-2004. This value may change with better predictive tools for TP. The majority of TP in eroding streambanks was isolated to a few particular regions. A Getis-Ord hotspot analysis of total mass P per erosion feature yields 3-4 hotspots and two coldspots representing areas where total masses of P are consistently high and consistently low respectively (Fig. 6). Extruding the erosion features by total mass P (Fig. 7) shows how a few erosion features contain the majority of total mass P. By isolating the components of total mass P (TP concentration and mass of erosion feature), it is clear the mass of the erosion feature drives the total mass P more than the concentration of TP. This can also be explained by the range of data: the mass of erosion features ranges from <1 MT to >1,000 MT while the calculated TP concentrations only range from 400 to 500 mg/kg. Proportioning the total P load of Allen Brook from 1999-2004 by watershed size, 3191 kg TP represents 40% of the total P delivered to Lake Champlain via Allen Brook from 1999-2004. Thus, bank erosion could be a substantial portion of the total P loading to Lake Champlain, at least from Allen Brook.

Ongoing schedule

A subset of the above 900+ soil samples will be selected to represent a range of geographic locations, soil textures, and TP and MM-P concentrations within the larger dataset. These samples will be analyzed for acid ammonium oxalate extractable P (P_{ox}) to assess the long-term potential bio-availability of riparian soils in Chittenden County.



*Figure 6. Getis-Ord hotspot analysis of total mass of TP per erosion feature estimated by TP concentration regression applied to NRCS silt values*mass of erosion feature.*

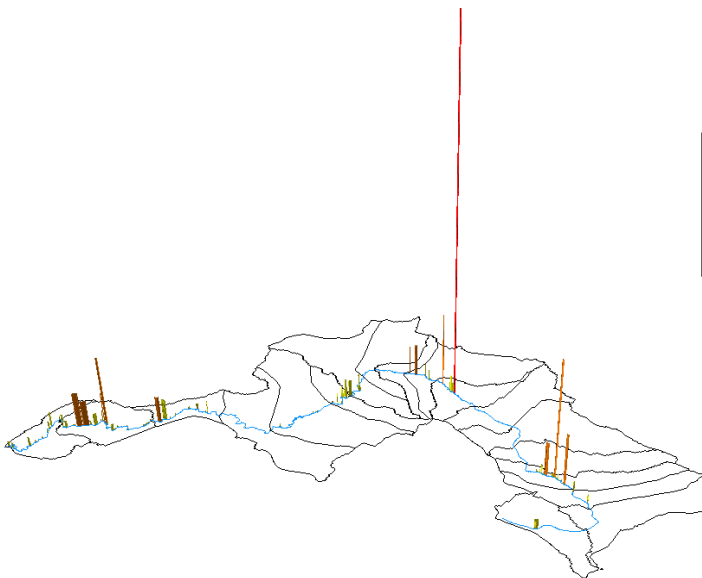


Figure 7. Erosion features extruded by estimated total mass of P along Allen Brook.

Training

This project is training a M.S. candidate (Eulaila Ishee) in all aspects of the proposed research. In addition, the project is providing valuable training for a number of undergraduate students majoring in Environmental Sciences and student interns in UVM STREAMS program. During the first field season we had the help of two students (Edward Garcia and Angel Garcia) from Universidad Metropolitana of Puerto Rico as part of the UVM STREAMS internship program. We also had the assistance of a UVM McNair scholar from the Rubenstein School, Maya Thomas. These three students have given presentations on the research they performed in 2009. Angel Garcia presented at the annual STREAMS conference and Maya Thomas at the UVM Student Research Conference (citations below). In addition, Angel was admitted to UVM's graduate program in the Geology Dept. and commenced studies in the fall of 2010. For the second field season (2010), we again had the assistance of two students from Universidad Metropolitana (Dorielys Valetin and Karoline Rios) and one UVM Environmental Sciences undergraduate (Alison Nord). Dorielys Valetin presented at the Universidad Metropolitana and at the annual STREAMS conference (citations below). All three students were able to attend the Lake Champlain 2010 Conference. During this past school year, undergraduate student Charlotte Ford (UVM Environmental Sciences) was trained and assisted with field and lab work.

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